The First AACG Carbon Symposium

June 26th - 27th 2025

Istanbul Technical University, Istanbul

ABSTRACTS

of

The First AACG Carbon Symposium

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Istanbul Technical University (Retired), Turkish Carbon Society (ferhat@itu.edu.tr)

Research Asst. Prof. Dr. Selmi Erim Bozbağ
Koç University (sbozbag@ku.edu.tr)

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ORAL PRESENTATIONS

Graphene Oxide: From Fabrication to Applications

Hui-Ming Cheng[1,2]*, Wencai Ren*[2]
[1]1 Institute of Technology for Carbon Neutrality, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China
[2] Shenyang National Laboratory for Materials Science, Institute of Metal Research, the Chinese Academy of Sciences, Shenyang 110016, China
Email: hm.cheng@siat.ac.cn

Graphene has excellent properties, such as high mechanical strength and modulus, high thermal and electrical conductivities, very good thermal and chemical stabilities, and unique electronic properties. So graphene is expected to be used in various applications. Graphene oxide is one of the most versatile graphene materials which has been widely investigated and used. We have developed a free radical oxidation method to produce graphene oxide in large quantity with low pollution, and then a centrifugal fluid alignment process to assemble graphene oxide membrances with different thicknesses which can be converted into graphene membranes with a high thermal conductivity. These graphene membranes have been used in electronics and optoelectronics for efficient thermal management. Interestingly, we have found that partially-reduced graphene oxide has a high gold extraction capacity from electronic waste (e-waste), one order of magnitude higher than other reported gold adsorbents. During extraction, the reduced graphene oxide reduces >95% gold ions to metallic gold, avoiding elution and precipitation necessary in post-adsorption processing. Moreover, this reductive adsorption of gold by reduced graphene oxide is found different from (predominately) electrostatic adsorption of other metal ions, hence, having precise gold extraction without adsorption of other 14 elements present in e-waste. Most recently we found that graphene nanosheets can be "sintered" into strong bulk graphite materials at a mild temperature of 45 degree C. However, great efforts are still needed for the research, development, and commercialization of graphene oxide and their deriatives.

Advances in carbon-based cathodes for high-performance Li-O_2 batteries

Wei YU[1], Zhaohan SHEN[2], Minghao LIU[2], and Hirotomo NISHIHARA[1,2]*

[1] Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai, Japan.
[2] Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai, Japan.
*hirotomo.nishihara.b1@tohoku.ac.jp

Lithium–oxygen (Li–O_2) batteries hold great promise due to their high theoretical energy density exceeding 3500 Wh/kg. However, some serious problems remain, such as high charge overpotential, cathode degradation, and the resulting limited cycle life. Our research focuses on innovative carbon cathodes to address these issues, utilizing defect engineering, catalytic synergy, and nanoconfinement strategies. One key breakthrough is the development of an edge-site-free, topological-defect-rich graphene mesosponge (GMS) cathode. Unlike conventional carbon cathodes, GMS possesses a highly mesoporous structure with numerous topological defects but no edge sites. While the developed porosity enables a high discharge capacity exceeding 6700 mAh/g, the topological defects serve as active sites for the foramtion of amorphous lithium peroxide (Li_2O_2), leading to a low charge plateau of approximately 3.6 V[1]. This structure enables ultra-long cycle stability. Furthernore, we developed a binder-free, hierarchically porous graphene cathode, which exhibits remarkable areal (>30 mAh/cm^2), mass (>6300 mAh/g), and volumetric (>480 mAh/cm^3) capacities[2]. The cathode structure minimizes stacking and enhances mass transport, enabling an optimized energy density of 793 Wh/kg and an extended cycle life exceeding 260 cycles. Another advancement is the sequential catalysis approach, which integrates defective carbon with Ru nanoparticles [3]. This system facilitates a two-step Li_2O_2 decomposition process, where basal defects drive the initial reaction at a lower potential, followed by Ru-assisted decomposition at a higher potential. The synergy between these two mechanisms significantly reduces overpotential and enhances battery longevity. We also investigated the nanoconfinement effect by utilizing carbon-coated anodic aluminum oxide membranes with precisely controlled nanochannel sizes (25–200 nm)[4]. Our findings indicate that smaller pores (~25 nm) induce film-like Li_2O_2, which decomposes at a lower charge potential (~3.2 V), while larger pores (~200 nm) favor crystalline Li_2O_2, requiring a higher potential for decomposition[5]. This study highlights the crucial role of nanoarchitecture in optimizing charge efficiency. As an alternative strategy, we explored the use of a carbon thin film with interconnected macropores as a cathode, integrating separate catalysts for Li_2O_2 deposition and decomposition. This approach enabled us to achieve an exceptionally high areal capacity of 38 mAh/cm^2.These innovations demonstrate the potential of advanced carbon cathodes to overcome the limitations of Li–O_2 batteries, bringing them closer to practical applications in next-generation energy storage systems.

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From Graphite to Graphene – Production and Application

Feiyu Kang[1,2]

[1]Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen, Guangdong Province 518055, China
[2]School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China
Email: fykang@tsinghua.edu.cn

Abstract

It is known that China possesses a lot of natural graphite resource, one is flake graphite and the other is microcrystalline graphite, both types may be prepared into fine particle with high purity, which may be used as anode materials for lithium-ion battery. Natural graphite is also the raw materials for the graphene, which has been extensively used in all kinds of energy devices including supercapacitor, lithium-, sodium-, potassium- and zinc-ion battery, etc. Besides, flexible graphite and graphene film are applied to thermal management of the above devices.

Keywords: Graphite, graphene

New Approaches to Control Porosity and Surface Property of Porous Carbons

Jin MIYAWAKI[1,2,*]

[1] Institute for Materials Chemistry and Engineering, Kyushu University, Japan
[2] Interdisciplinary Graduate School of Engineering Science, Kyushu University, Japan
*miyawaki@cm.kyushu-u.ac.jp

Excellent adsorption characteristics of porous carbon materials, such as activated carbons (ACs), are governed by both porosity and surface property. This talk introduces our trials to control porosity and surface property of porous carbons.

As the first trial, a novel pressurized physical activation (gas activation) method is introduced as a simple production method for ACs with highly developed pore structures (**Fig. 1**). Our previous study [1] has shown that, during physical activation, activating agent molecules preferentially react with solid carbon on the outer surfaces of particles and microdomains, which are a basic structural unit of artificial carbon materials, prior to a penetration into core areas. That is, conventional atmospheric pressure physical activation is diffusion-limited reaction. Therefore, if a diffusivity of the activating agent can be improved, a more homogenous activation reaction could be achieved for all microdomains within each carbon particle, allowing a high development of pores and a high activation yield even by physical activation method. To increase the gas diffusivity, it has been reported that pressurization is effective [2]. Based on this knowledge, we demonstrated the effectiveness of pressurization on pore developments during the physical activation. The improved diffusivity afforded remarkable increases in specific surface area and pore volume together with a unique pore size distribution for the prepared AC [3].

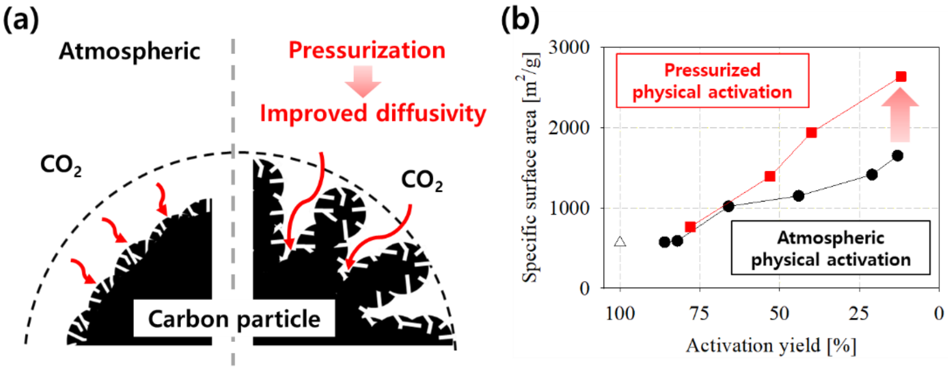

Fig. 1. (a) A schematic of improved diffusivity of activation agent (CO_2) by pressurization and (b) a relationship of activation yield to degree of pore development for ACs prepared by atmospheric and pressurized physical activation methods with CO_2 as an activating agent [3].

The second trial is about a pore-size-selective control of surface property. As most of ACs have wide pore size distribution, the transformation of less-useful pores to valuable ones is effective to maximize the adsorption performance. In addition to the pore structure, surface property also influences on adsorption characteristics especially for polar molecules. Herein, we proposed a new strategy incorporating three sequential treatments – selective molecular pre-masking, surface modification, and unmasking – for pore-size-selective control of the surface properties of ACs (**Fig. 2**) [4]. To demonstrate this strategy, *n*-nonane was physically adsorbed as a molecular pre-masking agent; subsequent room-temperature ozonation was applied for surface modification to realize wide pore-selective hydrophilization. As this approach can be employed using a variety of molecular masking agents and/or surface modification methods, thereby a design of porous carbons with own surface properties for each pore depending on the size could be achieved.

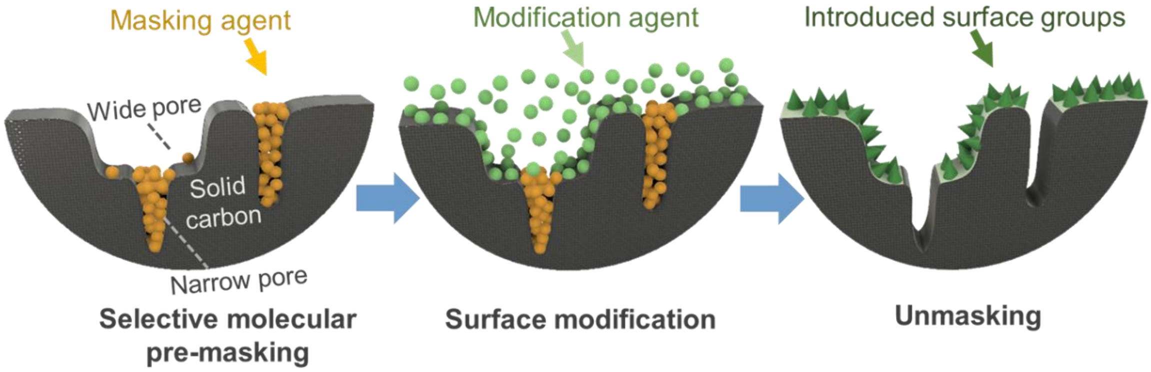

Fig. 2. A schematic of new three-step strategy for pore-size dependent surface modification of porous carbons [4].

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Converting CO_2 and biomass wastes into carbon materials and applications in electric double-layer capacitors (EDLC)

Jarrn-Horng Lin

Department of Materials Science, National University of Tainan, Taiwan
*janusjhlin@mail.nutn.edu.tw; janusjhlin@yahoo.com.tw

CO_2 capture and utilization (CCU) and sustainable recycling of biomass wastes are two main research trends. Recently, we have developed new methods for converting CO_2 and biomass wastes into carbon nanotube/carbon nanofibers (CNT/CNFs) and hierarchical porous carbons, respectively. In this work, we not only designed a novel catalyst (Ni/MgO) to convert CO_2 into CNT/CNFs at a mild temperature of 500 °C, but also turned spent coffee grounds into mesopore domain porous carbon with CO_2 activation. These carbon materials are used as the main components in the electrode materials of electric double-layer capacitors (EDLC). The specific capacitance of the as-prepared two-electrode EDLC can reach 224 F g-1 using an organic electrolyte of 1.0 M $TEABF_4$/PC, and the energy density can be as high as 56 Wh kg^{-1}, the charge-discharge cycles at high voltage window of 2.5-2.7 V retaining approximately 98 % after 50,000 cycles. Our findings will provide new insights on CCU and the circular chemical economy.

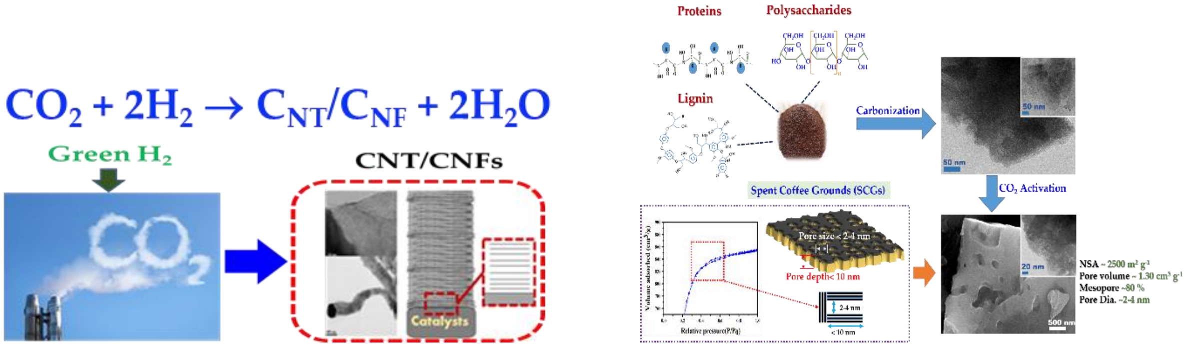

Fig.1 Left panel: catalytic converting CO_2 into CNT/CNFs, and right panel: transforming spent coffee grounds into porous carbons.

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Design and transport properties of novel field-effect transistors based on carbon nanomaterials

Dong-Ming SUN[1,*], Hui-Ming CHENG[1,2]
[1] Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, Shenyang, P. R. China, [2] Institute of Technology for Carbon Neutrality, Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China
* dmsun@imr.ac.cn

The report mainly introduces our research progress in recent years on electronic devices based on single-walled carbon nanotubes. (1) Using bottom-up low-dimensional material synthesis technology and top-down micro-nano processing technology strategies, we built subnanometer-scale single-atom-channel fin transistors (FinFETs) and the arrays with new structural designs for post-Moore devices. (2) A vertical heterostructure silicon-graphene-germanium transistor was constructed, combining graphene materials with mixed-dimensional semiconductor materials to achieve a high-speed transistor with terahertz application potential, providing the new way of the design and development of new nanoelectronic devices. (3) A hot-emitter transistor based on double mixed- dimensional graphene/germanium Schottky junctions that uses stimulated emission of heated carriers to achieve a subthreshold swing lower than 1 millivolt per decade beyond the Boltzmann limit and a negative differential resistance with a peak-to-valley current ratio greater than 100 at room temperature. (4) We use the unique structural characteristics and excellent physical and chemical properties of carbon nanotubes to meet the important needs of multi-functional integration and flexibility of flexible wearable electronic devices, and realize carbon nanotube flexible photovoltaic and storage integrated devices, flexible carbon nanotubes neuromorphic vision chip, building a highly integrated, ultra-sensitive prototype chip that integrates sensing, storage and computing functions.

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Irradiation damage of graphite

Ke Shen,*

College of Materials Science and Engineering, Hunan University, Changsha 410082, China

*shenk@hnu.edu.cn

Graphite is a critical material in nuclear reactors, where its thermal and mechanical stability significantly impact reactor safety and longevity. Understanding the irradiation-induced changes in graphite is essential for optimizing its performance in extreme environments. Traditionally, point defects are known to reduce thermal conductivity (κ) by increasing phonon scattering; however, recent studies have revealed an unconventional phenomenon where energetic particle irradiation can enhance the cross-plane κ of graphite. Specifically, the introduction of spiro interstitial defects through irradiation covalently bridges neighboring basal planes, simultaneously increasing acoustic phonon group velocity and reducing phonon-phonon scattering, leading to a nearly twofold κ enhancement. This discovery challenges the conventional understanding of defect-phonon interactions and provides new insights for thermal management in radiation-intense environments.

In parallel, precise measurement of irradiation-induced dimensional changes in graphite is crucial for reactor applications. Using nanoscale crack-free highly oriented pyrolytic graphite (HOPG) prepared through mechanical exfoliation and high-temperature annealing, recent studies have corrected historical data affected by Mrozowski cracks. Employing helium ion irradiation and atomic force microscopy (AFM), researchers accurately quantified thickness and lateral expansion across a temperature range of 200–750°C under low irradiation doses (<1 dpa). Results indicate that prior studies underestimated c-axis expansion due to microcrack absorption, while a newly developed feature-point line-segment method has significantly improved the accuracy of a-axis expansion measurements.

These findings offer essential data for understanding graphite's irradiation response, optimizing its radiation resistance, and ensuring the safe operation of advanced nuclear reactors, including gas-cooled and molten salt reactors. The insights gained contribute to extending reactor lifespans and refining post-irradiation design strategies, highlighting the crucial role of graphite in next-generation nuclear energy systems.

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Carbon Nanotubes as Superior Conductive Additives: Enhancing Performance of Lithium Ion Batteries

Yoong Ahm KIM

Department of Polymer Engineering, Graduate School, School of Polymer Science and Engineering, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju, 61186, South Korea

*yak@chonnam.ac.kr

Conductive carbon materials play a vital role in constructing efficient electrode networks in lithium-ion batteries (LIBs). With increasing demands for higher energy density and cost efficiency in battery development, carbon nanotubes (CNTs) are emerging as superior alternatives to conventional carbon black conductive additives. This presentation explores the advantages of CNTs as advanced conductive materials in LIB electrodes. We demonstrate how CNTs enhance cathode performance through improved electrical networks, contributing to higher energy density and battery efficiency. In anode applications, we examine CNTs' role in silicon-based systems, where they provide essential mechanical stability and electrical conductivity. The presentation also highlights how CNTs enable innovative electrode fabrication processes, including water-based and dry production methods, supporting environmentally conscious manufacturing. While addressing the current challenges of CNT implementation - including production costs, dispersion uniformity, and metal impurity concerns - we present potential solutions for their successful integration in commercial LIB production. This work provides insights into optimizing CNT-based conductive networks for next-generation battery technology.

Single-wall carbon nanotube films and their hybrids

Chang Liu[1*]

[1] Institute of Metal Research, Chinese Academy of Sciences, Shenyang, China
*cliu@imr.ac.cn

High purity and high-quality single-wall carbon nanotubes (SWCNTs) and their assemblies with excellent physiochemical properties can be used in a wide range of applications. We prepared high-quality SWCNTs efficiently in a large scale by a floating catalyst CVD method [1]. SWCNTs were directly deposited onto a porous substrate to form thin films with tunable thickness and in meter-scale [2]. By controlling the size of SWCNT bundles and their inter-tube resistance, the performance of SWCNT transparent conductive films were further improved, approaching that of ITO films on flexible substrates [3]. The SWCNT films were used to fabricate silicon heterojunction solar cells, which show desirable power conversion efficiency. A flexible SWCNT/Bi_2Te_3 hybrid was prepared by magnetron sputtering using SWCNT network as a scaffold. The obtained SWCNT/Bi_2Te_3 film shows excellent thermoelectric performance and flexibility [4, 5]. A high-entropy alloy nanowire/SWCNT membrane electrode was prepared, which showed desirable hydrogen evolution catalysis performance in an acid solution [6].

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Carbon-Based Anodes for Na-Ion Batteries:

A Comparative Study of Electrochemical Performance and Enhanced Ion Storage

Gamzenur ÖZSİN[1*], Mohammed Mustafa ALMARZOGE[2], Metin GENÇTEN[2]

[1] Department of Chemical Engineering, Bilecik Şeyh Edebali University, Bilecik, Türkiye
[2] Department of Department of Metallurgy and Materials Engineering, Yıldız Technical University, İstanbul, Türkiye
*gamzenur.ozsin@bilecik.edu.tr

Integrating renewable energy sources like solar and wind into the electrical grid demands robust, large-scale energy storage solutions capable of managing fluctuations in energy supply and handling peak load requirements. Among the various available energy storage technologies, lithium-ion (Li-ion) batteries stand out due to their superior efficiency, high energy density, and reliability. These attributes have led to their extensive adoption not only in portable electronic devices and electric vehicles but also increasingly in stationary applications designed to stabilize renewable energy systems. As a result, the rapid expansion and integration of Li-ion battery technology have significantly contributed to reducing global reliance on fossil fuels, supporting broader efforts toward sustainable energy infrastructures [1,2]. Nevertheless, the uneven geographical distribution of essential raw materials has introduced geopolitical tensions and supply-chain vulnerabilities associated with Li-ion batteries. This issue underscores the need to advance alternative battery technologies capable of replacing lithium-based solutions, thereby addressing sustainability and supply concerns [3-5].

Sodium-ion (Na-ion) batteries offer significant advantages over Li-ion batteries, particularly in the ongoing transition toward sustainable and scalable energy storage solutions. Sodium is far more abundant and evenly distributed globally than lithium, reducing material costs, supply-chain risks, and geopolitical dependencies. Additionally, Na-ion technologies utilize environmentally benign materials, facilitate simplified recycling processes, and offer enhanced safety characteristics, while also leveraging established battery manufacturing infrastructures [6]. Although Na-ion batteries currently exhibit lower energy densities compared to conventional lithium-based technologies, they are particularly well-suited for stationary and large-scale energy storage applications, where safety, cost-effectiveness, and environmental sustainability often outweigh considerations related solely to energy density.

For advancing sodium-driven technologies, the development of effective electrodes, is crucial due to several fundamental and practical challenges. Unlike lithium ions, sodium ions have a larger ionic radius and different electrochemical behavior, resulting in limited intercalation capability and lower energy density when traditional electrode materials are used. Therefore, designing functional anodes with suitable structural characteristics is essential to achieve efficient ion storage, enhance cycling stability, and maximize overall battery performance. Among the diverse classes of electrode materials explored for Na-ion batteries, carbon-based materials stand out as exceptionally promising candidates due to their intrinsic structural flexibility, economic advantages, and practicality. Carbon materials are particularly attractive owing to their natural abundance, low raw-material costs, and ease of synthesis, facilitating scalable production with excellent reproducibility and precise control over morphological properties. Moreover, the structural versatility inherent in carbon materials enables precise modulation of key physicochemical characteristics, such as porosity, surface area, crystallinity, and degree of graphitization, which play crucial roles in determining electrochemical performance. Importantly, carbonaceous anode materials typically demonstrate favorable electrochemical characteristics, including substantial ion insertion capacities, stable cycling performance, and excellent electrical conductivity—features essential for high-performance ion storage. Additionally, the flexible and adaptable synthesis methods available for carbon-based materials enable fine-tuning of structure-performance relationships, allowing researchers to engineer customized electrode. In this context, the present study systematically investigates various carbonaceous materials and heteroatom-doped carbon structures as potential anodes for Na-ion batteries, thoroughly evaluating their electrochemical performance in conjunction with their synthesis techniques and detailed microstructural features. Ultimately, these advanced carbon-based materials not only address critical technical challenges within Na-ion battery technology but also represent a promising, economically viable, and environmentally friendly pathway toward sustainable, scalable, and efficient energy-storage solutions.

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Probing the Interfaces Between 2D Materials and Liquid Metals

Yu Lei

Tsinghua Shenzhen International Graduate School
leiy07@sz.tsinghua.edu.cn

Liquid exfoliation is a scalable and effective method for synthesizing two-dimensional (2D) nanosheets (NSs) but often induces contamination and defects. Here, we use liquid metal gallium (Ga) to exfoliate bulk layered materials into 2D NSs at near room temperature, utilizing the liquid surface tension and Ga intercalation to disrupt van der Waals forces. In addition, the process can transform the 2H-phase of transition metal dichalcogenides into the 1T'-phase under ambient conditions. This method produces high aspect ratio, surfactant-free 2D-NSs for more than 10 types of 2D materials that include h-BN, graphene, $MoTe_2$, $MoSe_2$, layered minerals, etc. The subsequent Ga separation via ethanol dispersion avoids the formation of additional defects and surfactant contamination. By adjusting initial defect levels of the layered materials, we can customize the metallicity and/or defectiveness of 2D NSs for applications such as birefringence-tunable modulators with exfoliated h-BN, and enhanced hydrogen evolution with defective MoS_2. This approach offers a strategy to optimize liquid metal/2D interfaces, preserving intrinsic properties and enabling practical applications, potentially transforming optics, energy conversion, and beyond.

Keywords

Liquid metal, graphene, boron nitride, 2D materials, liquid exfoliation

Carbon Aerogels: Revolutionizing Material Science

Can Erkey[1,2,*]

[1]Department of Chemical and Biological Engineering, Koç University, Istanbul, Turkey,
[2]Koç University Hydrogen Technology Center, Istanbul, Turkey
*: cerkey@ku.edu.tr

Carbon aerogels have emerged as a revolutionary class of materials, redefining how researchers design, manipulate, and apply porous carbon frameworks in advanced technologies. These materials—formed by pyrolyzing organic precursor gels such as resorcinol-formaldehyde under inert conditions—offer a rare combination of properties: extremely low densities (as low as ~0.16 mg/cm^3), ultrahigh specific surface areas (500–2500 m^2/g), hierarchical pore structures, and high electrical conductivity. These characteristics have propelled carbon aerogels beyond their initial scientific curiosity status into a versatile platform for addressing some of the most pressing challenges in materials science and engineering.

In the past decade, advances in synthesis and processing have significantly expanded the accessibility and utility of carbon aerogels. Innovations in supercritical drying, freeze-casting, and green precursor selection have lowered the barriers to fabrication while allowing precise control over pore morphology and network connectivity. At the same time, strategies like heteroatom doping (e.g., nitrogen, sulfur, phosphorus) and the incorporation of secondary phases (graphene, metal oxides, carbon nanotubes) have greatly enhanced their chemical functionality and stability. As a result, modern carbon aerogels can be custom-tailored for diverse roles, from electrochemical performance enhancement to thermal and environmental management.

The impact of carbon aerogels spans a broad spectrum of applications. In energy storage and conversion, their conductive, high-surface-area networks enable faster charge/discharge kinetics and improved active material utilization in supercapacitors, lithium-ion batteries, and fuel cells. In catalysis, carbon aerogels provide both a stable support and—when properly doped—an active matrix for metal-free or hybrid catalytic systems, showing promise in reactions such as oxygen reduction, CO_2 reduction, and hydrogen evolution. Their use in capacitive deionization and pollutant adsorption highlights their potential for water purification, while oil-absorbing variants have demonstrated extreme absorption capacities ideal for environmental cleanup. Furthermore, their ultralow thermal conductivity, coupled with high-temperature stability, opens avenues for energy-efficient insulation in aerospace and industrial contexts. Emerging applications in soft electronics and pressure/chemical sensing leverage their piezoresistive and functional surface properties, further extending their relevance.

Beyond individual applications, carbon aerogels embody a broader shift in material science: the move from bulk-driven to architecture-driven functionality. Their performance is not dictated solely by composition, but by their engineered nanostructure—an idea increasingly central to fields such as metamaterials, energy device engineering, and advanced composites. This capacity to fine-tune properties through structure challenges long-standing paradigms, enabling ultralight materials to perform roles traditionally reserved for dense or metallic counterparts.

Looking ahead, challenges remain in terms of scaling production, improving mechanical robustness, and integrating carbon aerogels into industrial systems. However, continued advances in materials processing, sustainability (e.g., biomass-derived aerogels), and hybridization are rapidly bridging these gaps. Carbon aerogels are no longer confined to the lab—they are entering real-world applications, inspiring new thinking, and enabling next-generation solutions across science and industry.

This presentation will explore the evolution and multidimensional impact of carbon aerogels, showcasing how their unique properties are catalyzing innovation across material science domains and how they continue to redefine what is possible in engineered carbon materials.

Sonicated carbon nanotube catalysts for efficient point-of-use water treatment

Xin Yang[1], Yuan Chen[1,*]

[1] School of Chemical and Biomolecular Engineering, The University of Sydney, Darlington,
New South Wales, 2006, Australia
*yuan.chen@sydney.edu.au

Persulfate-based advanced oxidation processes are suitable for point-of-use water treatment to alleviate freshwater demands in various scenarios[1–3]. Carbon nanotube (CNT) catalysts enable nonradical oxidation pathways to selectively target unsaturated organics and bacteria[4,5], however, the nature of their active sites and mechanisms is unclear without scalable and controllable synthesis methods[3,4,6]. Herein, we reported highly active sonicated CNT catalysts by selectively introducing carbonyl (C=O) groups and retaining their graphitic structures, via inputting a series of sonication energy (**Fig. 1**). The optimal sonicated CNT catalysts achieve the highest 2,4-dichlorophenol (DCP) removal rate (4.80 μmol g−1 s−1) reported so far. Two nonradical oxidation pathways (67% from singlet oxygen ($^1O_2$) oxidation and 31% from direct electron transfer (DET) process) contribute to 98% of DCP removal. Detailed correlation, deactivation, and theoretical calculation analysis reveal the oxygenous functional groups and defects on CNTs, which sonication energy inputs can control, can shift the two nonradical mechanisms. The optimal CNT catalyst membrane devices including flat membrane cell and hollow fiber filtration can maintain high catalytic performance for 30 hours in real water treatment (**Fig. 2**), advancing the application in point-of-use water treatment.

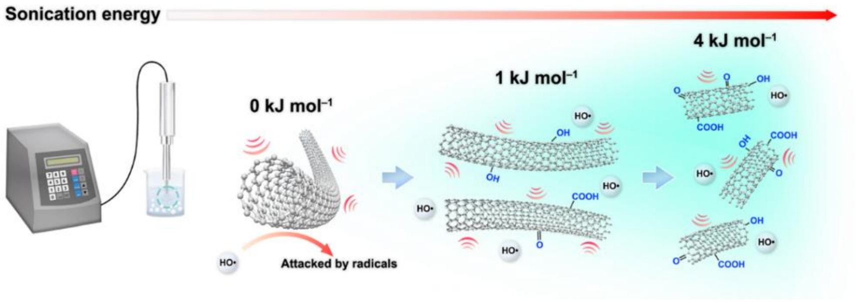

Fig. 1. Schematic illustration of the synthesis of sonicated CNT catalysts.

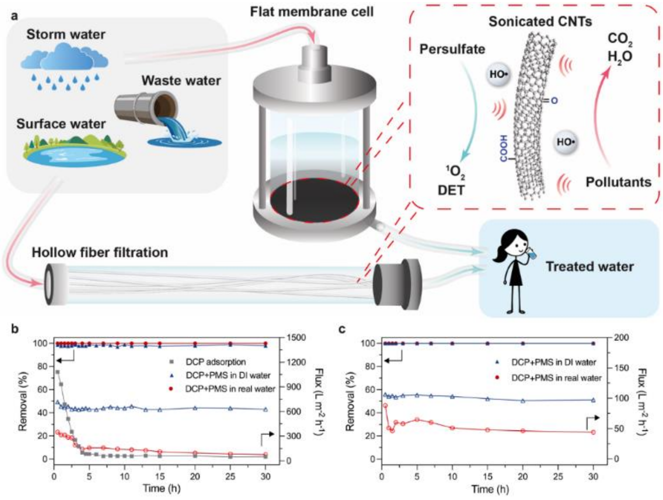

Fig. 2. (a) Schematic illustration of sonicated membrane devices. The long-term performance of flat membrane cell (b) and hollo fiber filtration (c) using the optimized sonicated CNTs.

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Harnessing Graphene's Potential for Polymer Electrolyte Membrane Fuel Cells: Challenges and Future Horizons

Selmiye Alkan Gürsel[1,2*] , Begüm Yarar Kaplan [2,3] , Alp Yürüm[1,2] , Sina Abdolhosseinzadeh[4],
Navid Haghmoradi[5], Ahmet Can Kırlıoğlu[6], Adnan Taşdemir[1],
Bilal İskandarani[7], Naeimeh Rajabalizadeh Mojarrad[2]

[1]Faculty of Engineering and Natural Sciences, Sabancı University, Istanbul, Turkey
[2]Sabanci University Nanotechnology Research and Application Center (SUNUM), Istanbul 34956, Turkey
[3]Section of Chemistry for Technology, Department of Industrial Engineering, University of Padova, via F. Marzolo 9 I-35131 Padova, Italy
[4]Laboratory for Functional Polymers, Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, CH-8600 Dübendorf, Switzerland
[5]Karlsruhe Institute of Technology, Karlsruhe, Germany
[6]Vlaamse Instelling voor Technologisch Onderzoek (VITO), Boeretang 200, 2400 Mol, Belgium
[7]Chemical and Biomolecular Engineering, University of California, Irvine, CA USA
*selmiye@sabanciuniv.edu

The advancement of economically viable and resilient catalytic materials for polymer electrolyte membrane (PEM) fuel cells and electrolyzers represents a critical frontier in sustainable energy research. This investigation addresses the fundamental challenges of electrocatalytic performance, longevity, and economic feasibility, with particular emphasis on optimizing reaction kinetics for the oxygen reduction reaction (ORR) in PEM fuel cells. The disparate electrochemical environments of ORR necessitate catalyst architectures with distinctly optimized properties—platinum-based metals predominating in cathodic ORR applications. Graphene-based materials have emerged as exceptional catalyst support platforms due to their remarkable specific surface area, superior electronic conductivity, and enhanced chemical stability. The strategic deposition of platinum (Pt) nanoparticles on graphene substrates yields heterogeneous catalytic systems that substantially minimize precious metal loading while concurrently amplifying electrocatalytic activity through the exceptional charge carrier mobility inherent to graphene[1].

In this comprehensive investigation, ultra-fine platinum nanoparticles (2–3 nm) synthesized using various graphene architectures—including pristine graphene nanoplatelets, reduced graphene oxide (rGO), functionalized graphene derivatives, and graphene-based hybrid materials—demonstrated significant enhancements in catalytic efficiency, reduced platinum utilization, and superior electrochemical performance metrics in operational fuel cell systems [1,2]. The research further explores advanced photocatalytic deposition methodologies, wherein transition metal ions function simultaneously as hole scavengers and surface modification agents for partially reduced graphene oxide (PRGO), facilitating the controlled photoreduction of Pt^{4+} precursors. Detailed structural and electrochemical characterization of the resultant Pt electrocatalysts revealed that cobalt-based hole scavengers promote preferential nucleation and growth of platinum nanoparticles at specific sites on the PRGO substrate, yielding predominantly metallic Pt species with significantly enhanced electrocatalytic activity[2]. Additionally, novel ceria-based components—specifically CeO_2 nanorods and CeO_2/nitrogen-doped rGO nanocomposites—were successfully integrated to further augment ORR kinetics and overall PEM fuel cell performance [3].

Despite significant advances in graphene-supported platinum catalysts for PEM fuel cells, key challenges persist including scalable production of consistent graphene materials, long-term stability of graphene-Pt interfaces, platinum agglomeration during cycling, and incomplete understanding of metal-support interactions at the nanoscale. Future perspectives include computational modeling with in-situ characterization to elucidate interface properties, incorporation of secondary metals to form Pt-alloys for reduced precious metal content, and development of hierarchical graphene structures with optimized mass transport. Integration of these catalytic systems into next-generation membrane electrode assemblies represents a crucial step toward commercial viability of graphene-enhanced PEM fuel cell technologies.

In this presentation, along with the studies our research group has conducted on graphene for PEM fuel cells, the aforementioned challenges and future directions will be discussed.

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Photocatalytic estrogen degradation by the composite of tin oxide fine particle and graphene-like carbon nitride

Shinji KAWASAKI*, Yuzuki Amino, Yosuke Ishii

Department of Life Science and Applied Chemistry, Nagoya Institute of Technology, Japan
*kawasaki.shinji@nitech.ac.jp

The impact of trace amounts of endocrine-disrupting substances (environmental hormones) present in rivers on ecosystems has become a significant concern. In recent years, efforts to purify the environment using photocatalysts have been progressing. Graphitic carbon nitride (g-C_3N_4) has attracted attention as a metal-free visible-light-responsive photocatalyst because it is composed of abundant and easily accessible elements, is easy to synthesize, and is chemically stable. In this study, we synthesized g-C_3N_4/SnO_2 composites and investigated their photocatalytic activity in the degradation of a representative environmental hormone, estrogen (E2).

The g-C_3N_4/SnO_2 composite was synthesized by placing a mixture of urea and tin acetate in a crucible and heat-treating it in an electric furnace under an N_2 flow at 550°C for 2 hours. The SnO_2 content was adjusted to weight ratios of 0, 0.3, 0.6, and 1.5 wt%. A 0.1 mM solution of E2 and the g-C_3N_4/SnO_2 composite was stirred in the dark for 3 hours to prevent photochemical changes before the light irradiation experiments. Simulated sunlight from a solar simulator (AM1.5G, 1000 W/m^2) was then applied. After irradiation, the solution was centrifuged to remove the composite sample, and changes in the E2 concentration were examined using photoluminescence (PL) measurements.

The g-C_3N_4/SnO_2 composite exhibited effective photocatalytic activity for degrading E2 under simulated sunlight. FT-IR measurements revealed that the g-C_3N_4/SnO_2 composite possesses structural units similar to those of the well-studied graphitic carbon nitride (g-C_3N_4). However, unlike g-C_3N_4, the XRD diffraction pattern of the g-C_3N_4/SnO_2 composite showed no sharp diffraction lines, indicating low crystallinity. The presence of tin in the tin oxide/SnO_2composite was clearly confirmed by XPS. However, no sharp diffraction peaks were observed in the XRD pattern, suggesting the presence of microcrystals. Detailed discussions on the photocatalytic mechanism will be presented at the symposium.[1]

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Sustainable Carbon Materials for Catalytic Applications

Yuan Chen[1,*]

[1] The University of Sydney, School of Chemical and Biomolecular Engineering,
Darlington, New South Wales 2008, Australia
*yuan.chen@sydney.edu.au
https://yuanchenlab.org/

Carbon materials are poised to play a pivotal role in building a more sustainable future. This talk will provide an overview of research activities in the Advanced Carbon Research Lab at the University of Sydney, focusing on two key areas: catalytic methane pyrolysis and the design of high-performance carbon catalysts.

Methane pyrolysis ($CH_4 \rightarrow 2H_2 + C$) is a promising method for producing hydrogen with low CO_2 emissions. However, its economic viability depends on effectively utilizing the solid carbon co-products.[1] Our research has shown that catalytic methane pyrolysis using low-cost iron ore catalysts produces carbon nano-onions (CNOs) encapsulated with magnetic iron cores. These CNOs exhibit dual functionality: they serve as efficient and recyclable Fenton catalysts for pollutant degradation and demonstrate a high adsorption capacity for antibiotics in wastewater.[2] Additionally, surface-oxidized CNOs show high catalytic activity for in situ electrochemical hydrogen peroxide (H_2O_2) production. By integrating these properties, we have developed a novel wastewater treatment process, turning carbon co-products from hydrogen production into value-added materials.[3]

Carbon-based catalysts hold great potential for a wide range of essential reactions. However, their practical application is often limited by structural inhomogeneity, poor stability, and a lack of fundamental understanding of their catalytic mechanisms. To address these challenges, we have developed model catalysts using carbon nanotube (CNT) substrates to host well-defined molecular catalysts. By constructing CNT cores with thickness-tunable covalent organic framework (COF) shells, we achieved controllable n-doping, which reduces the COF's bandgap and work function. This design significantly enhances catalytic activity for oxygen redox reaction.[4] We also found that introducing β-substituents to cobalt porphyrins adsorbed on CNT substrates can synergistically modulate cobalt properties and catalytic activity. An octafluoro-substituted catalyst exhibited >94% H_2O_2 selectivity and a high turnover frequency in an acid electrolyte.[5] A series of iron-based heterogeneous molecular catalysts were also used as model catalysts to map their degradation for oxygen reduction reactions in acidic electrolytes. Five degradation paths were quantified, and the beneficial role of electron-withdrawing substituents was revealed.[6] Our recent work on carbon catalysts derived from ZIF-8 through controlled carbonization processes further highlights the importance of balancing heteroatom coordination environments and graphitization degrees. These insights are critical for designing high-performance carbon catalysts with tailored properties.[7]

In summary, our research demonstrates the transformative potential of carbon materials in addressing global sustainability challenges. From enabling low-emission hydrogen production to developing advanced catalysts for clean energy and environmental applications, carbon materials offer innovative solutions for a sustainable future.

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Synthesis of Graphite Aggregates in Nonequilibrium Methane Plasma

İbrahim Burak Şen, Necip Berker Üner*

Department of Chemical Engineering, Middle East Technical University, Ankara, Türkiye
*nuner@metu.edu.tr

Gas-phase synthesis of particulate nanomaterials has been significantly extended employing flow-through RF plasmas within the last two decades1, however, successful processing of methane with these reactors has been rather elusive. Multiple studies have reported the difficulty of particle nucleation and rapid film formation on reactor walls, films that grow on the walls and detach continuously, leading to a contamination in the product that leaves the reactor. In this work, we employ online size separation methods by centrifugal means and investigate the solid products of a flow through Ar/CH4 plasma reactor. We focus on the parameters that affect the formation of crystalline and high-surface-area graphite, such as pressure, plasma power and residence time.

A capacitively-coupled RF plasma was generated in a 12 mm diameter quartz tube to ignite Ar/CH4 mixture in a pressure range of 10-60 Torr. Optical emission spectroscopy was performed on several points on the reactor to monitor the Swan band peak formation. Generated particles were first subjected to a mobility separation and then collected on a steel mesh to be characterized ex-situ via X-Ray diffraction (XRD), Raman spectroscopy, transmission electron microscopy (TEM) and scanning electron microscopy (SEM).

During operation, a thick film forms and detaches likely due to deposition of polyaromatic hydrocarbons, as evidenced by a smooth and brownish color (Figure 1a). By employing online size separation, the desired particulate products were decoupled from film formation, and SEM imaging indicated the selection of a very fine powder, essentially comprised of the particles nucleated in the Ar/CH4 plasma. A closer look via TEM indicated that particles do not fully form at low residence times, however, spherical primary particles began to appear as residence time was increased (Figures 1b-f). Increase in the residence time not only forms such particles but also increase the crystallinity. At the beginning of particle formation, no crystal planes were visible during high-resolution TEM imaging (Figure 1g). When residence time was increased crystal planes began to appear (Figure 1f). Measurement of the distance between the lattice fringes showed that these planes belong to (111) plane of graphite. We hypothesize that this indicates the completion of the formation of a 3-D particle from a few layers of graphene sheets, which can be seen in Figure 1d. This presentation will detail the link between material properties and operational parameters thorough actinometry, XRD, electron microscopy, and peak ratios in Raman spectroscopy.

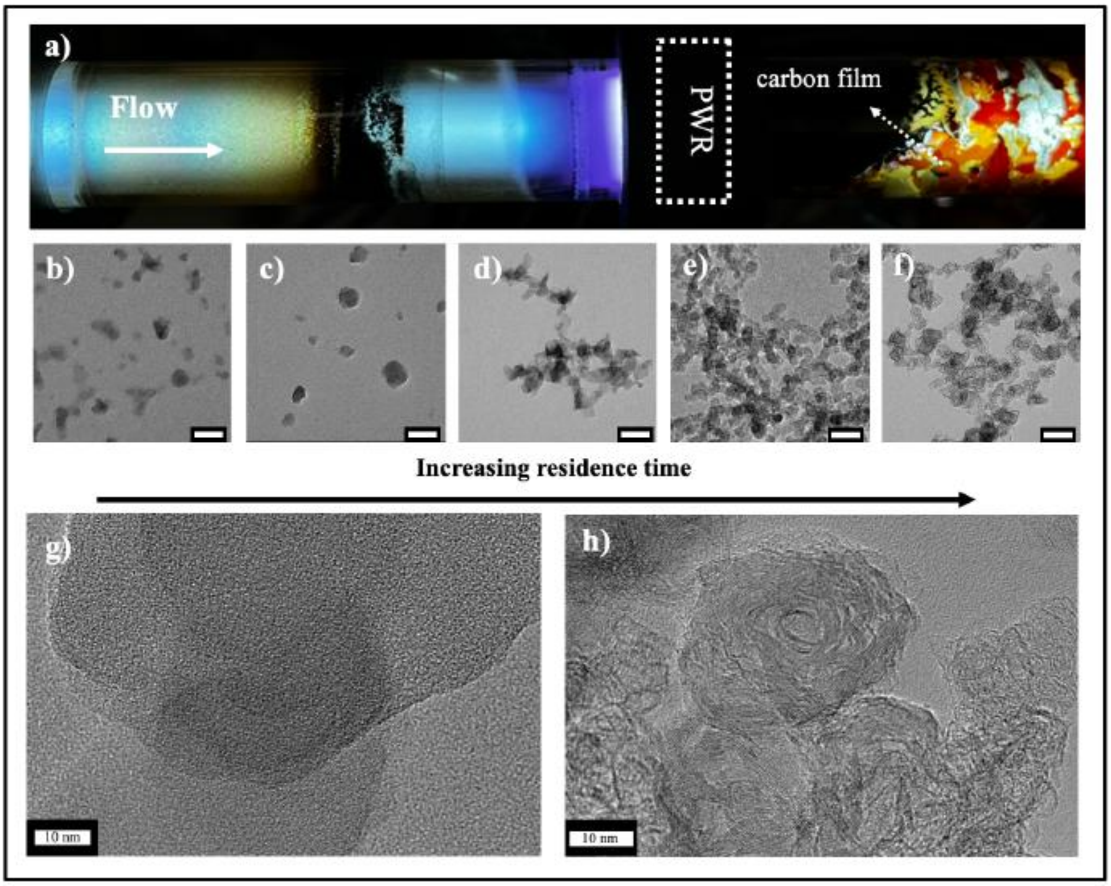

Figure 1. a) Photograph of the plasma reactor during synthesis, b) to f) TEM images of particles, g) HRTEM image of particles at low residence time, h) HRTEM image of particles at high residence time. Scale bars for images b) to f) are 50 nm in width.

Acknowledgement

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POSTER PRESENTATIONS

High performance LIB anode from NF3 plasma treated needle cokes

Chaehun Lim[1], Naeun Ha[1], Seongmin Ha[1], Chung Gi Min[1] and Young-Seak Lee[1,2,*]

[1]Department of Chemical Engineering and Applied Chemistry, Chungnam National University,
Daejeon, 34134, Republic of Korea
[2]Institute of Carbon Fusion Technology (InCFT), Chungnam National University,
Daejeon, 34134, Republic of Korea
(youngslee@cnu.ac.kr*)

NF_3 plasma treatments were used to improve the electrochemical properties of needle coke-based lithium-ion battery (LIB) anode materials. The effects of the NF_3 plasma treatments on the chemical, structural, and morphological properties of the needle cokes were evaluated and it was found that heteroatom doping and surface etching could take place at the same time. These reactions led to the development of N and F functional groups as well as micropores on the surface of the needle cokes. Significant improvement in the NF_3 plasma-modified needle cokes' cycling stabilities, rate capabilities, and discharge capacities were observed when they were applied to LIB performance testing. The resulting nitrogen functional groups and micropores improved the lithium storage capacities and rate performance by providing adsorption sites for lithium ions. The fluorine functional groups enhanced the cycle stability by forming LiF-based SEI layers. The effects of the NF_3 plasma treatment on the electrochemical properties were proved analytically. Needle cokes treated with NF_3 plasma are promising materials for fast charging LIB anodes with competitive discharge capabilities and strong stabilities.

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Capacitive deionization performance of N/F doped hierarchical porous carbons prepared by spontaneous silica etching

Seongjae Myeong[1], In Woo Lee[1], Seoyeong Cheon[1], Minah Kang[1], and Young-Seak Lee[1,2,*]

[1]Department of Chemical Engineering and Applied Chemistry, Chungnam National University,
Daejeon, 34134, Republic of Korea
[2]Institute of Carbon Fusion Technology (InCFT), Chungnam National University,
Daejeon, 34134, Republic of Korea
(youngslee@cnu.ac.kr*)

This study introduces a one-step, solvent-free approach for synthesizing nitrogen- and fluorine-doped hierarchical porous carbons (HPCs) for capacitive deionization (CDI). The synthesis method involves the co-gelation of silica and polyvinylidene fluoride (PVDF), followed by pyrolysis, during which in situ silica etching occurs due to the gaseous byproducts generated from PVDF decomposition. This strategy eliminates the use of hazardous solvents and labor-intensive purification steps. The resulting HPCs exhibit a high specific surface area of 1464.71 m²/g with abundant mesopores, facilitating efficient ion transport and charge storage. Electrochemical analysis reveals a specific capacitance of 179.5 F/g. In CDI performance tests using a 500 mg/L NaCl solution, the HPCs achieve an impressive salt adsorption capacity of 24.61 mg/g and an average adsorption rate of 3.69 mg/g/min. These outstanding results stem from the synergistic effects of the hierarchical pore network, which enhances ion diffusion, and the N/F functional groups, which improve electrosorption efficiency. This work demonstrates a sustainable and scalable route for fabricating high-performance HPCs and highlights the combined role of pore architecture and surface chemistry in advancing CDI technology.

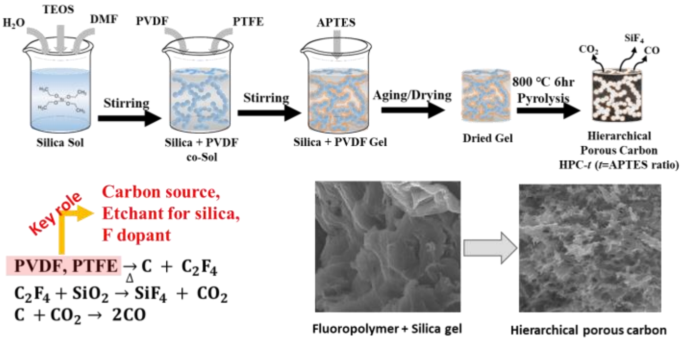

Fig 1. Preparation of HPCs by a silica etching with Fluoropolymers

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Improvement of Strength of Activated Coke by Oxidative Stabilization

Xiazhe Zhai[1], Kyoshiro Sakamoto[1], Koji Nakabayashi[1,2], Seong-Ho Yoon[1,2],
Jin Miyawaki[1,2,*]

[1] Interdisciplinary Graduate School of Engineering Sciences (IGSES), Kyushu University, Fukuoka, Japan,[2] Institute for Materials Chemistry and Engineering (IMCE), Kyushu University, Fukuoka, Japan
*miyawaki@cm.kyushu-u.ac.jp

Activated coke (AC) is an adsorbent employed in dry desulfurization (de-SO_X) and denitrification (de-NO_X) equipment particularly for thermal power plants and blast furnaces. This dry flue-gas treatment process is highly efficient and requiring minimal water, while simultaneously removing SO_X and NO_X, making it an environmentally friendly alternative to conventional wet flue-gas treatment methods. However, a persistent challenge in AC production arises from the inherent trade-off problem between specific surface area (SSA), which determines the de-SO_X/de-NO_X performances, and mechanical strength, which is essential for durability under industrial usage conditions. Achieving an optimal balance between these two properties of AC is critical but difficult, as the conventional AC production methods, which include kneading, forming (pelletization), carbonization, and activation steps using semicoke and binder pitch as feedstocks, often fail to reconcile these conflicting requirements.

In this study, an oxidative stabilization step, commonly used in carbon fiber production processes, was introduced into the AC production process to address this issue. The oxidative stabilization step promotes solid-phase carbonization and enhances the carbonization yield of binder pitch. Therefore, it can be expected to afford stronger interparticle bindings in the carbon pellet and AC.

Weight increase by the oxidative stabilization was confirmed by thermogravimetric analysis for formed pellets, suggesting an introduction of oxygen-bridges between binder molecules. The following carbonization process gave rise to remarkably improved tensile strength of the derived carbon pellets as shown in **Fig. 1**. Moreover, even after the activation, the superior strength was retained: ACs produced with oxidative stabilization showed higher tensile strength compared to those produced by traditional methods without oxidative stabilization up to 400 m^2/g of SSA.

The study highlights that the incorporation of oxidative stabilization breaks the traditional trade-off between SSA and strength by forming robust interconnections between particles. However, at higher activation degrees, these bonds seemed to be preferentially activated and/or damaged, causing SSA and strength to converge to similar levels. Overall, this research demonstrates a potential of oxidative stabilization to revolutionize the AC production.

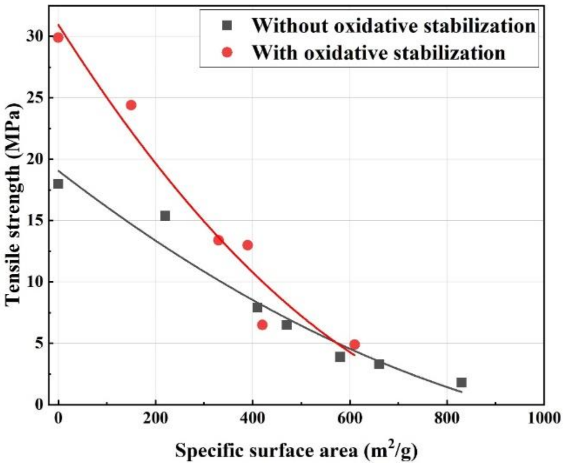

Fig. 1. Specific surface area vs. tensile strength of activated cokes prepared with/without oxidative stabilization

Production of High-Strength Porous Carbon Pellet without Activation Utilizing Dual Function of Marine Biomass Components

Xiazhe Zhai[1], Da He[1], Toru Kato[2], Chika Kosugi[3], Koji Nakabayashi[1,4],
Seong-Ho Yoon[1,4], Jin Miyawaki[1,4,*]

[1] Interdisciplinary Graduate School of Engineering Sciences (IGSES), Kyushu University, Fukuoka, Japan, [2] Environment and Process Research Department, The Japan Research and Development Center for Metals (JRCM), Tokyo, Japan, [3] Advanced Technology Research Laboratories, Nippon Steel Corporation, Chiba, Japan, [4] Institute for Materials Chemistry and Engineering (IMCE), Kyushu University, Fukuoka, Japan
*miyawaki@cm.kyushu-u.ac.jp

Because of high removal performance of SO_X and NO_X together with minimal water consumption, dry desulfurization and denitrification processes using activated coke (AC) as an adsorbent attract attentions. However, conventional AC production from coal involves an activation step that not only increases porosity at the expense of tensile strength but also incurs high energy consumption and costs.

Recently, we have reported that marine biomass (MB) rich in alkali and alkaline earth metals (AAEMs) can afford porous carbons just by the carbonization followed by water washing without costly activation step [1]. AAEMs in MB serve dual function of promoting pore formation during carbonization and subsequent blocking for the formed pores. Moreover, high solubility of AAEMs enables them to be washed away simply by water washing, giving rise to open-porous carbon particles.

This study leverages this unique property of MB to develop high-strength porous carbon pellets without the need for an activation step. As shown in Fig. 1, the production process includes carbonization, kneading with binder, forming (palletization), pyrolysis, and water washing. By eliminating the activation step, this method was able to avoid the trade-off problem between tensile strength and specific surface area (SSA), which is usually encountered in traditional AC production. In this study, two kinds of MB were used; *Undaria pinatifida* (Wakame in Japanese) and *Laminaria* (Kombu in Japanese). As shown in Table 1, after water washing, MB-derived carbon pellets achieved significantly high tensile strength (13–14 MPa) with SSA of 400–500 m^2/g, comparable to commercial AC. Surprisingly, the strength values surpassed those of "non-activated" carbon pellets derived from coal (8 MPa) and cedar (10 MPa). In contrast, the activation step of the coal- or cedar-derived carbon pellets induced a remarkable drop of the strength to obtain required porosity as AC, emphasizing an advantage of the proposed production method using MB as a raw material.

By capitalizing on the unique characteristics of AAEMs in MB, this study represents a breakthrough in production of porous carbon pellets. Achieving both high strength and sufficient porosity without activation not only lowers manufacturing costs but also minimizes environmental impact. These findings also underscore a potential of MB feedstock as a viable and sustainable alternative to coal and terrestrial biomass in industrial applications. Therefore, this research lays the foundation for innovative and environmentally friendly advancements in carbon material technology, contributing to carbon neutrality and sustainable development.

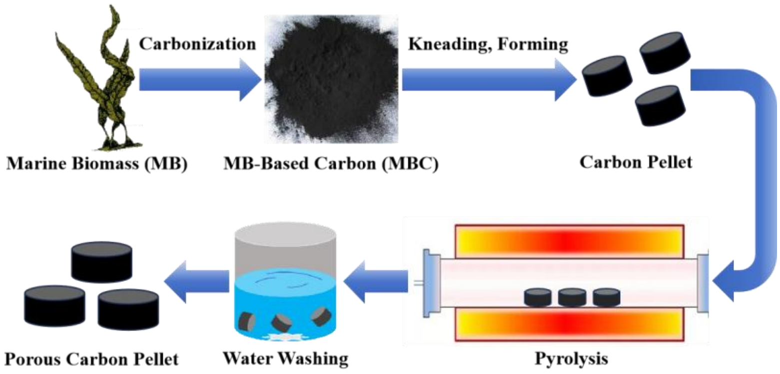

Fig. 1. Preparation process of MB-derived porous carbon pellets

Table 1. Comparison of tensile strength and SSA of porous carbon pellets derived from different raw materials

Raw material	Process	Tensile strength (MPa)	SSA (m^2/g)
Wakame	Pyrolysis	18.0	1
	Water washing	14.6	515
Kombu	Pyrolysis	17.7	3
	Water washing	13.4	446
Cedar	Pyrolysis	10.7	5
	Water washing	10.0	6
	Steam activation	5.4	456
Coke	Pyrolysis	7.9	7
	Water washing	7.8	7
	Steam activation	0.5	78

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Spatial Confinement for Constructing High-Performance Carbon/Sulfur Composite Electrode Materials

Shiyou Zheng*, Guangzhi YANG, Junhe YANG

School of Materials and Chemistry, University of Shanghai for Science and Technology,
Shanghai, China
*syzheng@usst.edu.cn

Lithium-sulfur batteries, as a new type of high-energy secondary battery system, possess advantages such as low cost, environmental friendliness, and high safety. They are expected to meet the demand for high energy density of future power batteries. However, due to the low electrical conductivity of sulfur, the generation of polysulfides during discharge, their dissolution and "shuttling", as well as the volume expansion of sulfur electrodes during charging, the battery capacity decays rapidly and fails to meet practical applications. In response to the problems existing in sulfur electrodes, the research group has conducted corresponding research work on key materials of lithium-sulfur batteries in recent years. Especially, by taking advantage of the superior microstructure and performance of carbon materials, we have constructed excellent carbon/sulfur composite electrode materials based on the strategy of spatial confinement. This work will focus on the construction of high-performance carbon/sulfur composite electrode materials and their electrochemical behaviors.

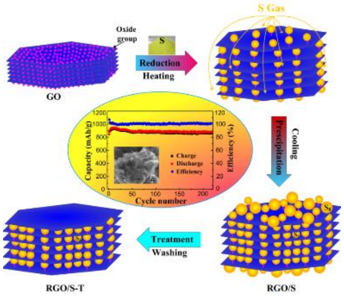

Fig. 1 Sulfur confined into reduced graphite oxides for Li-S battery cathode

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Effect of Carbon Cloth Composite Insertion on Lead-Acid Batteries: Characterization and High-Rate Cycling Performance

Shu-Huei Hsieh*

Department of Materials Science and Engineering, National Formosa University, Yunlin, Taiwan
* shhsieh@nfu.edu.tw

Carbonaceous materials improve lead-acid batteries (LABs), but challenges like hydrogen evolution (HER) and poor carbon-lead compatibility remain. To address these issues, we successfully developed carbon fiber cloth composites with a highly conductive Pb-C interface and demonstrated their formation, as shown in Fig.1 The composites were inserted into a single-cell LAB, where the battery capacity remained stable for over 100 cycles during 1C charge/discharge cycling, as shown in Fig. 2. In contrast, the capacity of a single-cell LAB without the composites declined after 20 cycles.

Figure 1 Schematic of the formation process of the Pb/CF bond

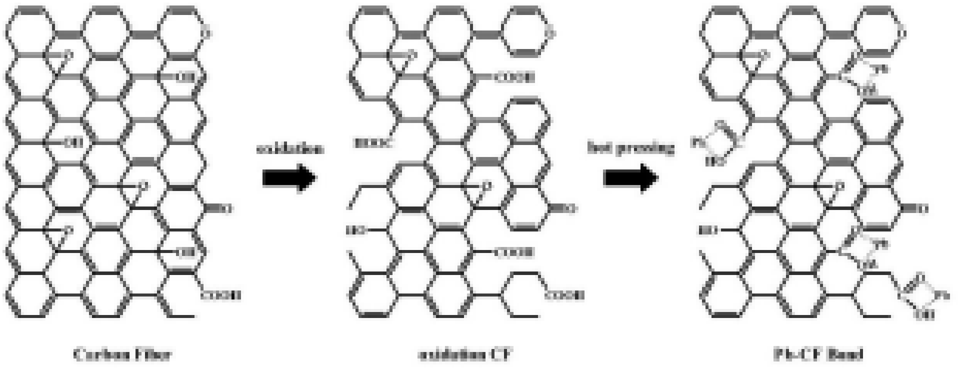
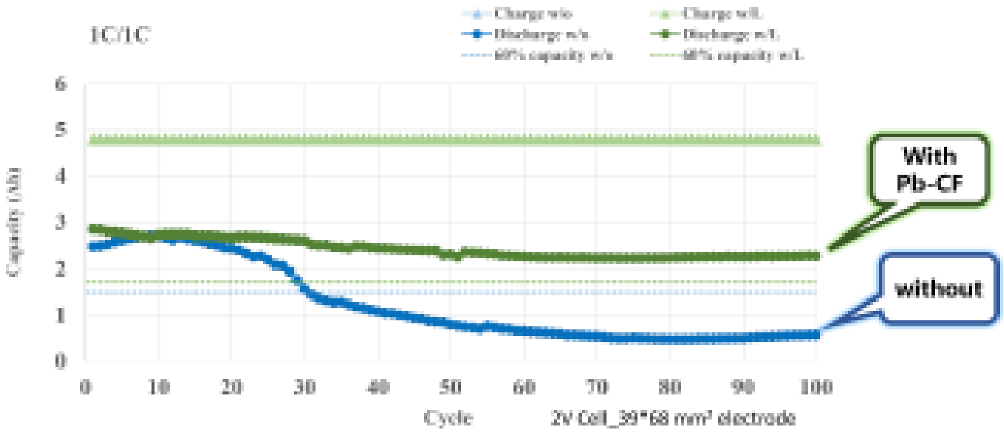


Figure 2 Impact of insert Lead-Carbon Cloth Composite on LAB



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Carbon Nanotube-Supported ZnPc Electrocatalysts for Selective Furfural Reduction: A Promising Strategy for Sustainable Biomass Conversion

Jiaxiang Chen [1]

[1] School of Chemical and Biomolecular Engineering, The University of Sydney, Darlington,
New South Wales, Australia, 2006

Carbon nanotubes (CNTs) exhibit high electrical conductivity, large surface area, and excellent electron transport, making them highly promising in electrocatalysis. In this study, we designed a high-performance ZnPc/CNT electrocatalyst for the selective electroreduction of furfural (FAL) to hydrofuroin (HF) via the furfural reduction reaction (FRR). The catalyst achieves high selectivity under mild potentials, with a Faradaic efficiency (FE) of 90%, surpassing other reported carbon-based single-atom catalysts (SACs) in both activity and selectivity toward HF. This superior performance is attributed to the strong electronic coupling between ZnPc and CNTs, which enhances charge transfer, improves ZnPc immobilization, and optimizes the electronic structure of active sites. Additionally, the unique weak binding capability of Zn in ZnPc/CNTs selectively promotes FRR over the competing hydrogen evolution reaction (HER) and unwanted side reactions, ensuring high HF yield. Electrochemical analysis confirms that π - π interactions between CNTs and furfural molecules enhance adsorption, facilitating C=O hydrogenation while suppressing undesired pathways.

Hydrofuroin is a potential precursor for sustainable jet fuel, making this reaction highly relevant for renewable energy applications. The development of ZnPc/CNTs not only advances efficient carbon-based electrocatalysis but also contributes to sustainable biomass valorization, offering an alternative to fossil fuel-dependent processes while minimizing environmental impact. These findings provide valuable experimental and theoretical insights for enhancing the role of carbon-based catalysts in electrocatalysis and their applications in green energy solutions.

Dual-functional graphitic carbon materials from methane pyrolysis for lithium-ion batteries

Justin PRABOWO[1], Yuan CHEN[1,*]

[1] School of Chemical and Biomolecular Engineering, The University of Sydney, Darlington,
New South Wales, 2006, Australia
*yuan.chen@sydney.edu.au

Carbon materials are essential for lithium-ion batteries (LIBs), the dominant energy storage devices. However, current carbon material production processes often have a high carbon footprint, causing a significant sustainability issue. For example, the specific carbon footprint of producing natural graphite used in LIBs is about 9.6 t CO_2 per t of natural graphite, and a recent study reported that the specific carbon footprint of synthetic graphite could reach 42.2 t of CO_2. Carbon black has a specific carbon footprint of about 3.5 t CO_2. Without considering purification and surface functionalization, carbon nanotube production alone would have a specific carbon footprint ranging from 21.2 to 47.1 t CO_2.

Methane pyrolysis ($CH_4 \rightarrow 2H_2 + C$) is a promising method for clean hydrogen production with large amounts of solid carbon materials as a coproduct. This study investigates the use of graphitic carbon materials produced from a catalytic CH_4 pyrolysis process via low-cost iron ore catalysts as anode materials and conductive additives in cathodes of LIBs (Figure 1).

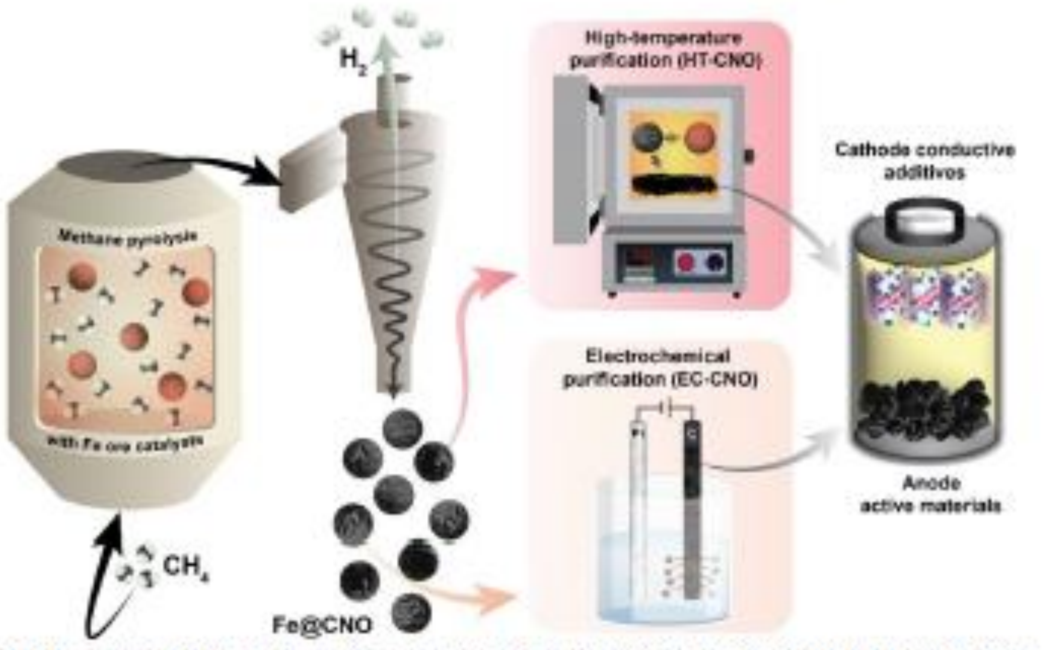

Fig. 1. Schematic illustration of carbon materials from CH4 pyrolysis for LIB applications. From left to right, H2 and carbon material synthesis using iron ore catalysts in a fluidized bed reactor; a cyclone separator separates solid graphitic carbon nano onions encapsulating Fe nanoparticles (Fe@CNO) from gas products; Fe@CNO undergoes subsequent high-temperature or electrochemical purification procedures to yield HT-CNO and EC-CNO respectively; purified CNOs are integrated as conductive additives in LFP cathodes and anode active materials in LIBs.

Design of a 2-D Plasma Reactor for Carbon Production through Methane Pyrolysis

Hüseyin ÖZTÜRK, Necip Berker ÜNER*

Department of Chemical Engineering, Middle East Technical University, Ankara, Türkiye,
*nuner@metu.edu.tr

The process of methane pyrolysis cracks methane in an O_2-free environment, and it leads to the synthesis of hydrogen and carbon, which is usually in powder form. Hydrogen is a crucial reactant in the chemical industry, especially in petrol refining and ammonia production, whereas the carbon can be used in various commodity products, such as rubbers, tires, various plastics, inks, paint, and battery electrodes, depending on a complex set of parameters that define the carbon, such as morphology, surface activation and conductivity. An industrially proven method of conducting methane pyrolysis is through the use of a plasma reactor, which has recently been demonstrated to be capable of production in scale.

Using a plasma for methane pyrolysis is attractive since the process is fully electrified and completely intermittent with very rapid turn-on/off times. However, the number of plasma reactors demonstrated for methane pyrolysis is very limited, and the application of chemical reaction engineering fundamentals to the design and operation of these reactors is currently absent in the literature. This study focuses on the design and characterization of a unique, 2-dimensional, gliding arc (GA) plasma reactor for conducting methane pyrolysis to produce carbon black and hydrogen (Figure 1). The GA is a warm plasma, and it combines high-temperature thermal conversion with non-equilibrium electron-impact chemistry. The reactor geometry was confined in one direction such that nearly all the gas was put in contact with the arc, increasing flow utilization in the reactor. Improvements on the residence time distribution were made through this geometrical modification, and gliding arc formation was visually and electrically analysed under direct-current excitation. Thermal characterization indicated that the thermal efficiency of the reactor can be made to be as high as 50%, meaning that half of the electrical energy was converted to heating the gas, whereas the rest was dissipated into the ambient through the reactor body. Preliminary experiments with CH_4-Ar mixtures have shown that conversion was relatively low, approximately 10%, indicating that the gliding arc should run at very high-power densities. However, preliminary analysis of the carbon produced indicated the carbon to be of graphitic structure (Figure 2a), and sintered forms have been observed through electron microscopy.

Development and Characterization of Tin Oxide-Reduced Graphene Oxide Composite as A High-Performance Anode Material For Lithium-Ion Batteries

Mert Arda KAYIŞLI[1, *], Prof. Dr. Reha YAVUZ[2, **]

[1] Department of Chemical Engineering, Istanbul Technical University, Istanbul, Türkiye, [2] Department of Chemical Engineering, Istanbul Technical University, Istanbul, Türkiye, [*]kayisli15@itu.edu.tr, [**]kmyavuz@itu.edu.tr

AIM

This research examines the potential of integrating tin oxide (SnO_2) with reduced graphene oxide (rGO) to create composite anodes aimed at improving lithium-ion battery performance. Incorporating rGO into SnO_2 seeks to mitigate key challenges such as volumetric expansion and capacity degradation inherent in pristine SnO_2 anodes. Leveraging rGO's structural and electrical advantages, SnO_2@rGO composites demonstrate superior capacity retention and stability compared to their pristine counterparts, suggesting notable advancements for future battery technologies.

Energy reliability remains a critical factor in industrial applications, with lithium-ion batteries emerging as a premier solution due to their commercial viability, environmental benefits, longevity, and cost-effectiveness. Enhancing these batteries' performance primarily involves optimizing components like cathode materials, anode materials, or electrolytes. Therefore, the development of high-capacity and durable anode materials is particularly crucial. Although graphite is commonly used as an anode material, its limited theoretical capacity necessitates exploring alternatives such as carbon derivatives, silicon, titanium oxides, and notably tin oxide (SnO_2). Despite SnO_2's higher theoretical lithium storage capacity—approximately 990 mAh/g—it encounters issues which are substantial volumetric expansion and rapid capacity fading. Hence, synthesizing composites with carbonaceous materials such as graphene has been proposed to address these challenges. [1-4]

METHOD

The synthesis process involved creating SnO_2 through hydrothermal treatment of $SnCl_2{\cdot}2H_2O$ mixed with hydrochloric acid and deionized water. Reduced graphene oxide was produced via a modified Hummers method followed by thermal reduction at 550°C. Various ratios of SnO_2@rGO composites were synthesized using chemical reduction processes involving ethanol dispersion and ascorbic acid treatment. On the other hand; for coin cell preparation, slurries containing active materials were coated onto copper foil before drying and cutting into sample sizes within argon-filled glove boxes. Battery performance was tested using charge-discharge measurements under specific conditions. [4, 5]

FINDINGS & CONCLUSION

XRD analysis identified peaks corresponding to both graphene and SnO_2; it was observed that graphene reduced the crystal size of SnO_2 in line with existing literature. Then, TGA analysis confirmed the presence of both carbon and tin oxide in samples since tin oxide is expected to lose mass at higher temperatures than carbon. Lastly, SEM images distinctly showed both graphene and tin oxide components. [4]

Pristine SnO2 anode initially exhibited a capacity close to 800 mAh/g but experienced about a 60% loss by the second cycle followed by another 40% over fifty cycles. In addition, the pristine rGO anode began near 400 mAh/g with a 25% loss by the fifth cycle. In alignment with efforts to overcome volumetric expansion via incorporating graphene oxide into SnO_2 matrices, the SnO_2@rGO (1/1) composite displayed an initial capacity around 800 mAh/g suffering only a 25% loss by its second cycle; other ratios are anticipated to yield similar results to those observed with the 1/1 ratio. In summary, combining SnO_2 with rGO addresses significant capacity fading issues, offering structural and electrical benefits that enhance stability and performance in lithium-ion batteries. [6, 7]

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Graphene Oxide Reduction via Pulsed Laser and High-Energy Ball Milling with NiCoFeMoW High-Entropy Alloy for Superior Electrocatalytic Oxygen Evolution Reaction

Hossein Mahdavi[a], Omer Şamil Akcan[b] ,Yağız Morova,[b, c], Uğur Ünal[* c,d,e], Hadi Jahangiri[*c]

a-Materials Science and Engineering, Koç University, Sariyer, 34450, Istanbul, Turkey, b-Department of Physics, Istanbul Technical University, Istanbul, Turkey, c-Koç University Surface Science and Technology Center (KUYTAM), Koç University, Sariyer, 34450, Istanbul, Turkey, d-Department of Chemistry, Koç University, Sariyer, 34450, Istanbul, Turkey, e- Koç University Hydrogen Technologies Center, Sariyer, 34450, Istanbul, Turkey

Developing cost-efficient and high-performance electrocatalysts for the oxygen evolution reaction (OER) is vital for sustainable energy technologies [1]. This study explores the reduction of graphene oxide (GO) using two distinct techniques: nanosecond pulsed laser irradiation and high-energy ball milling (HEBM). Structural analysis confirms that laser irradiation leads to partial reduction, whereas HEBM effectively removes oxygen-containing functional groups, achieving a greater degree of reduction. These reduction processes also impact the material's morphology—laser treatment induces localized "wrinkling" due to thermal effects, while HEBM results in "folding" caused by extended mechanical stress. To enhance the electrocatalytic properties, a NiCoFeMoW high-entropy alloy (HEA) was integrated with the reduced GO (rGO), altering the electronic structure of surface atoms and improving oxygen intermediate adsorption [2]. Electrochemical analysis demonstrates that the rGO-HEA composite significantly enhances OER activity, with BM-rGO/HEA exhibiting a low overpotential of 141.8 mV at 10 mA·cm^{-2}. This improvement is attributed to the synergistic effects between HEA and rGO, which facilitate charge transfer, increase active site density, and improve surface reactivity. These findings highlight the potential of rGO-supported HEAs as a promising alternative to noble-metal electrocatalysts, providing a scalable and eco-friendly approach for advancing water-splitting applications.

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Electrochemical Applications of Hybrid Organic Supercapacitors Based on Perilen Monoimide Diester Homodimer

Züleyha KUDAŞ[1*], Kamal ASADIPAKDEL[1], Demet DEMİRCİ GÜLTEKİN[2], Özgür Altan BOZDEMİR[3], Duygu EKİNCİ[3], Ali YAVARI[3], Mustafa Kemal BAYAZIT[1,4]

[1] Sabanci University Nanotechnology Research and Application Center (SUNUM), 34956, Tuzla-İstanbul, Turkey, [2] Department of Chemical Technology, Vocational School of Technical Science, Atatürk University, 25240, Erzurum, Turkey, [3]Department of Chemistry, Faculty of Sciences, Atatürk University, 25240, Erzurum, Turkey, [4] Faculty of Engineering and Natural Science, Sabancı University, 34956, Tuzla-İstanbul, Turkey, *zuleyha.kudas@sabanciuniv.edu

As global energy demand increases exponentially yearly, energy storage technologies continuously evolve. Supercapacitors are potential energy storage devices due to their exceptional features such as high power density, fast charge/discharge rate and stable cycling performance. Supercapacitors are classified into three categories based on the active electrode material and their charge storage mechanism: electric double-layer capacitors (EDLCs), pseudocapacitors, and hybrid capacitors [1]. In EDLCs, energy is stored electrostatically at the nanoscale electrode-electrolyte interface through the adsorption of electrolyte ions onto electrochemically stable and high surface area carbon materials. Unlike EDLCs, pseudocapacitors depend entirely on rapid and reversible electrochemical redox reactions, and energy is stored faradaically by electron charge transfer between the electrodes and the electrolyte ions. Compared to EDLCs, pseudocapacitors exhibit higher specific capacitance due to faradaic processes. However, since a chemical reaction occurs on the electrode surface during the charge-discharge process, pseudocapacitors have lower power density and a limited cycling life. Hybrid supercapacitors, which have emerged to minimize the disadvantages of EDLCs and pseudocapacitors, are combined systems that integrate non-faradaic charge storage processes with faradaic processes [2].

In light of this information, we aimed to construct hybrid organic supercapacitors based on Perylene Monoimid Diester Homodimer (PMIDE-HD). To this end, we first synthesized reduced graphene oxide (RGO), which is used as the active electrode material in organic supercapacitors. Then, using the synthesized RGO and PMIDE-HD molecules, flexible aluminum (Al) foil electrodes (2 cm×2 cm) were prepared, with the working electrode of the hybrid device (PMIDE-HD/RGO/Al) and the counter electrode (RGO/Al). The capacitive performance of these electrodes was investigated separately using cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), and electrochemical impedance spectroscopy (EIS) techniques in a three-electrode system. In the final stage, the asymmetric supercapacitor was designed by sandwiching the anode and cathode electrodes together with a gel electrolyte (Al/PMIDE-HD/RGO/PVA/RGO/Al), and the performance of the device was investigated using electrochemical techniques.

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Development of Carbon-Based Materials from Lignocellulosic Biomass using Thermal Conversion Method

Pınar ACAR BOZKURT[1], Özlem GÜMRAH[2], Zeynep Bilge ELÇİ[1], Meral YAŞAR[1],
Rukiye ÖZTÜRK[1]
[1] Department of Chemistry, Ankara University, Ankara, Türkiye,
[2] Department of Chemical Engineering, Atılım University, Ankara, Türkiye
*p3acar@hotmail.com

Biomass materials are recognized as a promising precursor for the production of carbon-based materials due to their high carbon content, low cost, easy accessibility, widespread availability, renewability, and environmental friendliness. Lignocellulosic biomass generally consists of plant materials that are not suitable for consumption as food. It is composed of cellulose and hemicellulose as the main polysaccharides, along with lignin, a phenolic polymer that also provides structural strength to plants. When subjected to thermal treatment, they can be converted into carbon-based materials due to their naturally high carbon content[1].

Carbon-based materials are being used in different fields in the growing energy sector as they embody numerous advantages such as diversity of morphology and structure, large surface area and pore size, good thermal stability and high electrical conductivity. In recent years, the use of biomass and industrial waste as carbon precursors has gained significant attention to meet the continuously increasing energy demand and to develop green and sustainable energy sources[2].

Various thermochemical conversion processes applied to biomass enable the production of high-quality and more useful fuels with properties equivalent to conventional fuels, or valuable products for the chemical industry. Pyrolysis is the most fundamental thermochemical conversion process used to convert biomass into a more valuable fuel[3]. In the pyrolysis process, the theoretically required amount of heat must be sufficient to break down the chemical structure of the organic material and facilitate the formation of new chemical compounds. The solid product obtained from biomass pyrolysis consists of ash and unconverted organic materials. It can be used for heat and electricity generation, and if it possesses a suitable pore structure and surface area, it can also serve as an adsorbent, asphalt filler, or activated carbon.

This study aims to evaluate the use of pyrolysis as a thermochemical conversion process that provides an alternative for the recovery of lignocellulosic biomass into carbon-based materials. In this study, pyrolysis experiments of almond shell selected as a biomass have been carried out in a tubular fixed-bed reactor at five temperatures (400, 450, 500, 550 and 600 °C). The solid product obtained from the pyrolysis process has been characterized using FTIR and SEM analysis methods and the BET surface area has been determined.

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Green hydrothermal synthesis of carbon dots from nettle (*Urtica dioica*) leaf

Zeynep Bilge ELÇİ[1], Pınar ACAR BOZKURT[1], Özlem GÜMRAH[2],
Meral YAŞAR[1], Rukiye ÖZTÜRK[1]

[1] Department of Chemistry, Ankara University, Ankara, Türkiye,
[2] Department of Chemical Engineering, Atılım University, Ankara, Türkiye
*zeynepbilgeelcii@hotmail.com

In recent years, carbon dots (CDs), one of the fundamental fluorescent carbon nanoparticles, have attracted increasing attention in various fields due to their unique properties and practical applications[1]. CDs, derived from carbon—a non-toxic, abundantly available element and a fundamental building block of life—exhibit high oxidation power, chemical stability, excellent biocompatibility, tunable photoluminescence, and versatile surface chemistry. These features make them highly suitable for a wide range of environmental applications, including photocatalysis, optics, chemical and biosensing, dielectrics, antimicrobial devices, and biomedical applications. To date, various approaches have been employed for the synthesis of CDs. However, green CDs synthesized from natural, sustainable sources have recently gained significant interest among researchers worldwide. The role of green chemistry in carbon nanoparticle synthesis lies in the development of alternative, environmentally friendly, and energy-efficient synthesis methods. Additionally, from a green chemistry perspective, the utilization of renewable and cost-effective carbon sources—such as biomass, vegetables, fruits, agricultural waste, and their derivatives—is of great importance[2,3].

The hydrothermal method, which aligns well with these green chemistry principles and represents an environmentally friendly approach to carbon nanoparticle synthesis, has garnered considerable attention. Compared to conventional methods, this technique enables chemical reactions to occur at lower temperatures and pressures and typically eliminates the need for organic solvents during the synthesis process. The hydrothermal method allows for the control of structural and morphological characteristics during synthesis, enhances synthesis efficiency, and supports its suitability and effectiveness for carbon nanoparticle production[4,5].

In this study, carbon nanoparticles with properties such as safety, non-toxicity, biocompatibility, and high stability has been synthesized using nettle leaves as an easily obtainable and low-waste natural carbon source. The hydrothermal method, which features a cost-effective, simple process and requires basic equipment, has been employed to achieve this synthesis.

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Hydrogen storage performance of activated and non-activated hydrochar

Ağah Yıldız[1], Esin Apaydın Varol[1], Murat Kılıç[1, *]

[1]Eskisehir Technical University, Faculty of Engineering, Department of Chemical Engineering
Eskisehir, Türkiye

mkilic3@eskisehir.edu.tr

This study investigates the hydrogen adsorption performance of activated (HTCAC) and non-activated hydrochar (HTCHC) derived from hazelnut shell under room temperature and high-pressure conditions. The activated hydrochar was obtained through chemical activation of the hydrochar using potassium hydroxide (KOH). Both HTCHC and HTCAC were comprehensively characterized by various techniques, including Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Diffraction (XRD), and N_2 adsorption-desorption analyses to evaluate their structural and compositional properties. Elemental analysis revealed that the carbon content increased from 51.30 wt% in the raw hazelnut shell to 71.71 wt% in the non-activated hydrochar and further to 83.33 wt% in the activated hydrochar, confirming the effective conversion of biomass into carbon-rich materials via hydrothermal carbonization and subsequent activation. The gravimetric hydrogen adsorption capacity of HTCHC was determined as 0.07 wt%, whereas HTCAC exhibited a significantly higher capacity of 0.38 wt% at 25 °C and 80 bar. Correspondingly, the volumetric hydrogen adsorption capacities were measured as 1.1 g/L for HTCHC and 5.86 g/L for HTCAC. These findings demonstrate that chemical activation substantially enhances the hydrogen storage capacity of hydrochar, underscoring its potential contribution to carbon-neutral technologies and the hydrogen economy.

Preparation and hydrogen adsorption performance of metal and boron doped biochar

Ağah Yıldız[1], Burcu Kiren[1], Murat Kılıç[1], Esin Apaydın Varol[1, *]

[1]Eskisehir Technical University, Faculty of Engineering, Dept. of Chemical Engineering
Eskisehir, Turkey.

eapaydin@eskisehir.edu.tr

This study explores the impact of different doping agents on the properties of biochar, specifically examining its hydrogen adsorption performance at room temperature and high-pressure conditions. Biochar was produced by pyrolyzing beech wood sawdust in a fixed-bed tubular reactor at 500°C. Biochar was doped with tinkal, boric acid, aluminum, and magnesium between 20% and 60% loading ratio using the wet impregnation method. The doped materials were subsequently characterized by using analytical techniques, including Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Spectroscopy (SEM-EDX), Fourier Transform Infrared Spectroscopy (FT-IR), and X-Ray Diffraction (XRD). Nitrogen adsorption-desorption isotherms were also employed to evaluate the surface area and porosity. The beech wood sawdust char demonstrated a hydrogen adsorption capacity of 0.08 %wt under the conditions of 25 °C and 80 bar. This study further evaluated the influence of different doping agents and ratios on the hydrogen adsorption performance of the biochar. The maximum hydrogen adsorption capacities achieved for biochar doped with various agents are as follows: 0.13 %wt for the biochar doped with 60 % aluminum, 0.15%wt for the biochar doped with 60% magnesium, 0.11 %wt biochar doped with 60% tinkal and 0.09 %wt biochar doped with 60% boric acid. These results indicate that doping with magnesium led to the highest hydrogen adsorption capacity among all other samples, suggesting its potential for enhancing the hydrogen adsorption properties of biochar at high pressure.

Biopolymer Based Carbon Aerogel Supported Pt Electrocatalysts Via Supercritical Deposition for Hydrogen Evolution Reaction

A. Alsuhile[1,3], P. S. Pein[2], B. Schroeter[2,4], Ş. B. Barım[1], S. E. Bozbağ[1], I. Smirnova[2,4], C. Erkey[1,3]*
[1]Department of Chemical and Biological Engineering, Koç University, Istanbul, Turkey,
[2]Thermal Separation Processes, Hamburg University of Technology, Hamburg, Germany
[3]Koç University Hydrogen Technology Center, Istanbul, Turkey
[4]United Nations University Institute for Water, Environment and Health (UNU-INWEH), Hamburg, Germany
**cerkey@ku.edu.tr*

Pt is the benchmark catalyst for the hydrogen evolution reaction (HER) in polymer electrolyte membrane (PEM) electrolyzers. However, its high cost and scarcity drive efforts to reduce Pt loading while maintaining performance. Low Pt loading often results in poor stability and durability, with the catalyst support playing a crucial role. While commercial Vulcan-XC-72 offers good conductivity, chemical inertness, and low cost, it suffers from Pt nanoparticles (PtNps) detachment, dissolution, and agglomeration. Biopolymer-based carbon aerogels (CAs) are a promising alternative due to their high surface area, multiscale porosity, and recyclability.

cellulose and chitosan biopolymers carbon aerogel were synthesized and PtNps were deposited via SCD at 15.5 MPa and 80°C for 24 hours, followed by thermal reduction under N_2 at 200°C.

SCD resulted in highly dispersed PtNps (<4 wt%) without significantly altering the support material structure, as confirmed by SEM, XRD, XPS, BET, and Raman analyses. HER activity was similar across the electrocatalysts due to the mass transfer limitations[1]; however, after stress test (1000 cycles at 100 mV/s), Pt-Vulcan showed a threefold increase in potential shift compared to CAs supported electrocatalysts (**Fig 1.a**). Due to the stress test, PtNps average mean diameters measured form TEM, increased from 1.3, 1.8, and 2.0 nm to 1.6, 2.4, and 3.0 nm for Pt-Cellulose-CA, Pt-Chitosan-CA, and Pt-Vulcan, respectively. The microporosity of cellulose-CA and N-heteroatoms in chitosan-CA created anchoring sites that reduced PtNps agglomeration which improved the PtNps stabilization. Chronoamperometry at 40 mV vs. RHE (**Fig 1.b**) showed an 80% current density drop for Pt-Vulcan within 20 hours, while Pt-Cellulose-CA and Pt-Chitosan-CA maintained stable performance, aligning with stress test results. Overall, CAs supported Pt electrocatalysts demonstrated superior stability and durability compared to Pt-Vulcan, attributed to their textured structure stabilizing small PtNps.

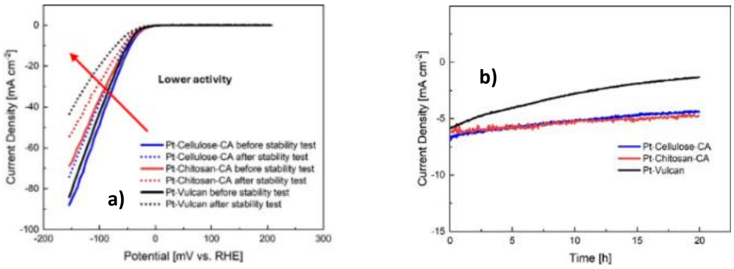

Figure 1: LSV before and after stress test (b) Chronoamperometry at 40 mV vs. RHE

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Microwave-Assisted Production of Nano Biocarbon from Beechwood Sawdust

Ayça Şevval AKALIN[1], Burcu KİREN[1], Esin APAYDIN VAROL[1*]

[1] Eskisehir Technical University, Faculty of Engineering, Dept. of Chemical Engineering
Eskisehir, Turkey

* eapaydin@eskisehir.edu.tr

Nano-biocarbon materials hold significant importance due to their potential applications in diverse fields, including environmental remediation and energy storage. Among the various production methods, microwave-assisted thermochemical conversion is considered the most effective and versatile approach for nano biocarbon synthesis due to its high carbon yield, tuneable structural properties, and compatibility with a wide range of biomass feedstocks. This study focuses on the effects of microwave operating conditions on the production of nano biocarbon from the solid product of biomass pyrolysis. Beechwood sawdust was the raw material for slow pyrolysis, where the final temperature was set at 500°C. Following pyrolysis, the solid product, characterized by a particle size of $D_p < 112$ µm, was subjected to an acidic treatment with a mixture of sulfuric and nitric acids in a volume ratio of 3:1. Biocarbon nanostructures were synthesized by microwave heating for different reaction times (1, 3, and 5 min) and power (50, 80, and 100%). The raw material and char were characterized using Thermogravimetric Analysis (TGA), Fourier Transform Infrared (FT-IR) Spectroscopy, Brunauer-Emmett-Teller (BET) Analysis, X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and proximate analysis. Additionally, the nano biocarbon samples were characterized by Dynamic Light Scattering (DLS) and Transmission Electron Microscopy (TEM). The results indicated that both acidic treatment and microwave heating significantly contributed to the formation of nanoparticles. A reduction of up to 13% in the nanoparticle dimensions was observed with increasing reaction time. The average particle size of around 300 nm was achieved at neutral pH with a reaction time of 3 min and full microwave power. According to Response Surface Methodology, Box-Behnken Design (RSM-BBD) results, a directly proportional relationship was identified between the increased microwave operating power and nanoparticle size.

Advanced Pt loaded Carbon-Based Electrospun Electrodes for PEM Fuel Cell Applications

Naeimeh Rajabalizadeh Mojarrad[1], Bilal Iskandarani[2], Selmiye Alkan Gürsel[1,3], Alp Yürüm[3], Begüm Yarar Kaplan[4, *]

[1]Sabanci University SUNUM Nanotechnology Research Center, 34956, Istanbul, Turkey
[2]Department of Chemical and Biomolecular Engineering, National Fuel Cell Research Center, University of California Irvine, 92697, USA
[3]Sabanci University, Faculty of Engineering and Natural Sciences, 34956, Istanbul, Turkey
[4]Departman of Industrial Engineering, University of Padova, 35122, Padova, Italy
*begumyarar@alumni.sabanciuniv.edu

The growing global demand for clean energy is accelerating advancements in environmentally friendly proton exchange membrane fuel cells (PEMFCs), with a strong focus on improving their performance, lifespan, and cost-effectiveness. In this context, two key priorities for the large-scale adoption of PEMFC technology are minimizing the use of costly platinum (Pt) particles in electrodes to meet cost targets and enhancing durability and efficiency through the optimized structural design of various components.[1, 2] Among the key components of PEMFCs, gas diffusion electrodes (GDEs) play a pivotal role. Each two-layered, carbon-based GDE consists of: a catalyst layer (CL), composed of Pt-based or non-Pt catalysts supported on carbon-based material, which hosts electrochemical reactions, and a highly porous gas diffusion layer (GDL), made of porous carbon cloth or paper, which efficiently transports reactant gases to the CL and removes the produced byproducts. Due to their high electrochemical surface area (ECSA), superior porosity, outstanding electrical conductivity, and good chemical and mechanical stability, various forms of carbon-based materials remain the most widely used electrode materials in these systems.[3] In this study, the versatile and scalable electrospinning technique was employed to fabricate high-surface-area, freestanding fibrous carbon-based cathode electrode materials for low-humidity PEMFC applications.[3] The prepared electrodes (P(VDF-TrFE)/Pt/CB/S-SiO_2) consisted of inexpensive sulfonated silica nanoparticles (S-SiO_2), Pt, carbon black (CB), and poly (vinylidene fluoride-co-trifluoroethylene) (P(VDF-TrFE)) as the carrier polymer—marking its first reported use for this purpose in the literature. To assess the impact of carrier polymer type, the addition of S-SiO_2 nanoparticles, and fabrication methods on electrode performance and durability in PEMFCs, three additional electrode types were prepared alongside (P(VDF-TrFE)/Pt/CB/S-SiO_2): electrospun PVDF-based electrodes (PVDF/Pt/CB/S-SiO_2) and (PVDF/Pt/CB/Nafion®), as well as conventionally sprayed electrodes. The chemical structure, morphology, electrochemical properties, performance, and durability of all prepared electrodes were thoroughly analyzed using various characterization techniques, including TEM, SEM, and EDS mapping. SEM micrographs of the (P(VDF-TrFE)/Pt/CB/S-SiO_2) mats revealed a uniform distribution of constituents throughout the structure. Furthermore, fuel cell tests demonstrated the exceptional performance of the (P(VDF-TrFE)-based) electrode, achieving a power density of 417.7 mW·cm^{-2} and a power output retention of 98.2% under low-humidity conditions (60% RH), outperforming both conventional sprayed (246.3 mW·cm^{-2}) and electrospun PVDF-based electrodes. This remarkable performance is attributed to the enhanced interaction between Pt and S-SiO_2 nanoparticles and their more uniform distribution.

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A Comparative Analysis of Microstructural Evolution and Mechanical Properties of Al_2O_3 Composites Reinforced with Multilayer Graphene and Boron Nitride Nanosheets

Yasemin Çelik and Ali Çelik

Eskişehir Technical University, Department of Materials Science and Engineering, 26555
Eskişehir, Türkiye

ybozkaya@eskisehir.edu.tr, acelik@eskisehir.edu.tr

Alumina (Al_2O_3) is a widely used ceramic in various engineering applications, such as cutting tools, wear resistant materials and biomedical implants, due to its high strength, hardness and wear resistance, relatively low density, high-temperature stability and chemical inertness. However, its inherent brittleness limits its utilization in these applications. Two-dimensional (2D) materials, such as few- or multilayer graphene (MLG) and hexagonal boron nitride nanosheets (BNNSs) are promising reinforcements due to their ability to maximize the interface contact area with the matrix phase, enable homogeneous distribution within the matrix, and possess outstanding mechanical properties. In this study, multi-layer graphene and BNNSs were prepared by grinding of natural flake graphite and hBN powder in a planetary mill, followed by homogenization. The exfoliated materials were then incorporated into Al_2O_3 matrix in various amounts and sintered by spark plasma sintering (SPS) technique. The morphology of the exfoliated materials and the microstructures of sintered composites were analyzed by scanning electron microscope. Vickers hardness and fracture toughness of the monolithic Al_2O_3 and the MLG/Al_2O_3 and BNNSs/Al_2O_3 composites were determined. The efficiency of MLG and BNNSs in improving the toughness of the Al_2O_3 matrix will be compared and discussed in this presentation.

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Innovative Deposition Strategies for Carbon-Supported Pt Catalysts in Electrochemical Hydrodeoxygenation of Biomass-Derived Oxygenate

Busra Cetiner[1], Jeffrey R. Page[2,3], Ioulia Valla[2,3], Alp Yürüm[1,4*], Selmiye Alkan Gursel[1,4*]

[1] Faculty of Engineering and Natural Sciences, Department of Materials Science and Nanoengineering, Sabancı University, Istanbul, Turkey,
[2] Department of Chemical and Biomolecular Engineering, University of Connecticut, 191 Auditorium Rd, Unit 3222, Storrs, CT 06269, USA
[3] Center for Clean Energy Engineering, University of Connecticut, 44 Weaver Rd, Unit 5233, Storrs, CT 06269, USA
[4] SUNUM Nanotechnology Research Centre, Sabancı University, Istanbul, Turkey
*selmiye@sabanciuniv.edu
*alp.yurum@sabanciuniv.edu

Electrochemical hydrodeoxygenation (EC-HDO) is an innovative and sustainable technique for converting biomass-derived oxygenates into biofuels under near-ambient conditions, eliminating the need for external hydrogen (H_2)[1]. While EC-HDO offers advantages over conventional thermochemical methods, achieving selective production of fully deoxygenated hydrocarbons remains a challenge. This study investigates novel synthesis methods for carbon supported Pt electrocatalysts that have the potential to increase the EC-HDO activity for of biomass derived oxygenates, such as phenol.

Two carbon-centric catalyst preparation strategies were explored. The first method employed carbon paper as a conductive substrate for the electrodeposition of Pt nanoparticles via chronoamperometry. The hydrophilic surface of the carbon paper facilitated uniform Pt deposition, yielding crystallites of 4.27 nm (XRD) and clusters averaging 40 nm (SEM). The carbon paper's hierarchical porosity and conductivity were critical in stabilizing Pt dispersion and enhancing electron transfer. The second approach utilized waste-derived carbon in a novel one-step electrophoretic deposition (EPD) process to directly fabricate Pt nanoparticles onto carbon paper [2]. Here, the carbon matrix served dual roles: as a support for Pt and as a sustainable, cost-effective material derived from waste precursors. Applying a controlled current/voltage to the carbon paper's hydrophilic surface produced surface-localized Pt clusters (~80 nm diameter, SEM-EDS), avoiding penetration into the carbon fiber structure. This method highlights the versatility of carbon-based substrates in tailoring catalyst morphology and accessibility. Surface activity analysis from cyclic voltammetry (CV) confirmed that the carbon-Pt hybrid systems exhibited exceptional catalytic activity, attributed to the synergistic effects between Pt nanoparticles and the carbon support's high surface area and electrical conductivity. The carbon paper's robust framework further ensured mechanical stability during prolonged operation.

This study demonstrates the successful synthesis of innovative carbon-supported Pt electrocatalysts using renewable carbon substrates—carbon paper and waste-derived carbon—through two distinct, advanced fabrication methods: electrodeposition and electrophoretic deposition (EPD). These carbon-centric strategies not only highlight the critical role of renewable carbon supports in optimizing catalyst architecture but also align with circular economy principles by repurposing waste carbon sources. Moving forward, these novel carbon-Pt hybrid systems will be applied to electrochemical hydrodeoxygenation (EC-HDO) reactions.

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